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ABSTRACT

This booklet is one of a set of eight designed to be used in a self-paced introductory chemistry course in conjunction with specified textbooks and computer-assisted instruction (CAI) modules. Each topic is introduced with a textbook reading assignment and additional readings are provided in the booklet. Also included are self-tests (and answers), CAI module assignments, and suggested breakpoints for student-teacher consultations. Supplementary learning materials, including filmstrips, are also suggested. Each booklet contains specific cognitive objectives to be met by completion. This booklet covers basic biochemistry. (MH)

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ILS CHEM PAC No. 8

BIOCHEM

by

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West Chester State College
West Chester, Pennsylvania

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SP 021 429

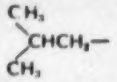
TABLE 1 *R Groups for the 20 α-Amino Acids Commonly Found in Proteins*[a]

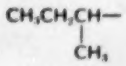
R is predominantly hydrocarbon

Glycine (Gly) H—

Alanine (Ala) CH_3—

Valine (Val)

Leucine (Leu) 

Isoleucine (Ile) 

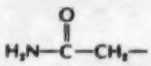
R contains — OH or other groups

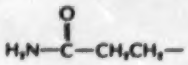
Serine (Ser) $HOCH_2$—

Threonine (Thr)

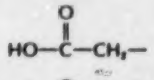
Cysteine (Cys) $HSCH_2$—

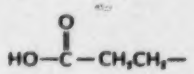
Methionine (Met) CH_3—S—CH_2CH_2—

Asparagine (Asn) 

Glutamine (Gln) 

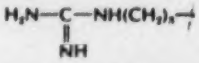
R is acidic

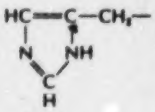
Aspartic acid (Asp) 

Glutamic acid (Glu) 

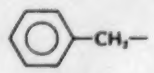
R is basic

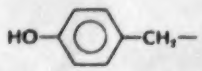
Lysine (Lys) $H_2N(CH_2)_4$—

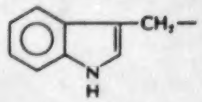
Arginine (Arg) 

Histidine (His) 

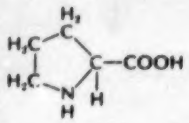
R contains a benzene ring

Phenylalanine (Phe) 

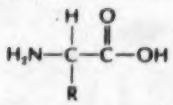
Tyrosine (Tyr) 

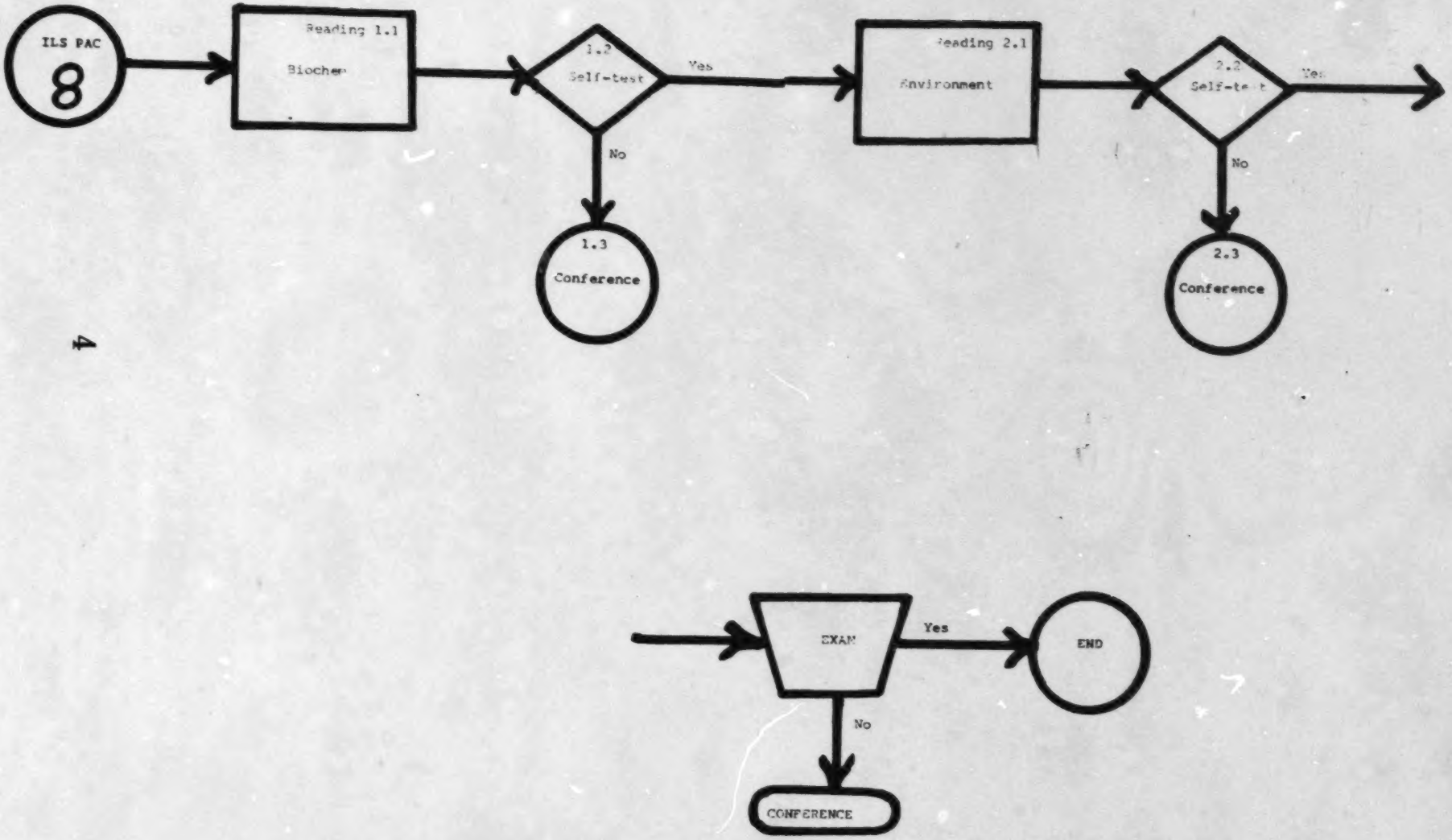
Tryptophan (Trp) 

A special case

Proline (Pro) 

[a] The name and conventional symbol of each compound are indicated. The general formula, which applies to all except proline, is




ILS PAC
8
Reading 1.1
Biochem
1.2
Self-test
Yes
No
1.3
Conference
Reading 2.1
Environment
2.2
Self-test
Yes
No
2.3
Conference
EXAM
Yes
END
No
CONFERENCE

OBJECTIVES

Upon completion of the ILS Chem Pac on Biochemistry the student should be able to

1. Biochemical Molecules

A. Given the structural formulas of a carbohydrate, lipid, protein, enzyme or vitamin, identify the functional groups present and classify the molecule as a carbohydrate, lipid, protein, enzyme or vitamin--in eight out of ten given structures.

B. State the basis of dividing carbohydrates, lipids, proteins, enzymes or vitamins into their respective major categories--or given examples of the several categories identify the classification which it represents--in eight out of ten given examples.

C. Given a particular carbohydrate, lipid, protein, enzyme or vitamin, predict the effect, if any, of the following possible reactions: hydrolysis, oxidation, fermentation, hydrogenation, addition of heat or acid--in eight out of ten given reactions.

D. Given the results of various laboratory tests, distinguish between carbohydrates, lipids, proteins, enzymes and vitamins or distiguish between the members of the following groups of biochemical compounds based on these results:

1. glucose, galactose, and fructose
2. sucrose, maltose, and lactose
3. fat and oil
4. soap and detergent

--in eight out of ten given molecules.

2. The Environment

Demonstrate a knowledge of a current environmental concern--such as those discussed in Reading 2.1--by composing a letter to your congressman (with address), stating a reasoned position on a current environmental issue, pointing out an error or an over-simplification in public policy which you perceive as having important chemical implications.

You should be prepared to substantiate--with documentation--any statements made in your letter.

ILS Chem Pac 8 - Biochemistry

[or "The Stuff of Which We Are Made"]

Introduction I

Biochemistry is concerned with the chemistry of living organisms. Most biological processes, such as digestion and metabolism, can be explained in terms of chemical reactions. Although biochemical reactions deal with large and complex molecules, most of them are combinations of the smaller units you studied in ILS Chem Pac 7.

Man is unable to produce these complex molecules from inorganic materials but a plant is able to take water, carbon dioxide, light, and a few trace minerals to produce carbohydrates, proteins, etc. First, we will look at some of these molecules.

Reading 1.1a - Read pages 233-236 in Medeiros, pages 253-269 in Sackheim & Schultz, and pages 322, 342-343, 360 & 386-387 in Holum.
Notes:

Carbohydrates are the class of organic compounds that includes sugars, starches, and cellulose. Carbohydrates are defined as polyhydroxyaldehydes or polyhydroxyketones or substances that yield these compounds on hydrolysis. Polyhydroxy means "containing many alcohol groups." Therefore, carbohydrates are alcohols [contain -OH(hydroxyl group)] and are also aldehydes or ketones [contain $>C=O$(carbonyl group).]

Carbohydrates are divided into monosaccharides, disaccharides, and polysaccharides. Monosaccharides are simple sugars and are called either aldoses or ketoses, depending upon whether they contain the aldehyde group(-CHO) or ketone ($>C=O$) groups. Aldoses and ketoses are further classified according to the number of carbon atoms they contain. An aldopentose is a five-carbon simple sugar containing a ketone group. Disaccharides are double sugars which, on hydrolysis, yield two simple sugars. Polysaccharides are complex sugars which, on hydrolysis, yield many simple sugars. In your reading, note the formulas and common names for the various sugars presented.

Aldehydes and ketones are reducing agents. When a reducing agent is treated with an oxidizing agent such as copper (II) hydroxide, a re-orange precipitate of copper (I) oxide is formed.

$$\text{aldehyde} + \underset{\text{blue solution}}{Cu(OH)_2} \xrightarrow{\text{heat}} \text{acid} + \underset{\text{red-orange precipitate}}{Cu_2O} + \text{water}$$

This is the basis for the various laboratory tests for sugars which contain an aldehyde or ketone group. The substances used, such as Benedict's solution or Fehling's solution, contain copper (II) hydroxide.

Glucose ferments in the presence of yeast forming ethanol and carbon dioxide. Fructose will also ferment; galactose will not readily ferment. Pentoses do not ferment.

Both the aldehyde end and the alcohol groups of the sugars can be oxidized to the corresponding acid.

There are three common disaccharides: sucrose, maltose, and lactose. Sucrose, upon hydrolysis, yields glucose and fructose; maltose yields two molecules of glucose; and lactose yields glucose and galactose. Looking at the formulas in your textbook you should observe that sucrose does not have a free aldehyde or ketone group whereas maltose and lactose do and thus the latter two yield a positive test with copper(II) hydroxide. Sucrose and maltose will ferment with yeast but lactose will not ferment when yeast is added.

Ploysaccharides are polymers of monosaccharides. Those formed from pentoses are called pentosans and polysaccharides formed from hexoses are called hexosans. Hexosans, with the general formula $(C_6H_{10}O_5)_x$, include starch, cellulose, glycogen and dextrin.

Comparison of Polysaccharides with Monosaccharides and Disaccharides

Property	Monosaccharides & Disaccharides	Polysaccharides
Molecular weight	low	very high
Taste	sweet	tasteless
Solubility in water	soluble	insoluble
Size of particles	pass through a membrane	do not pass through a membrane
Test with $Cu(OH)_2$	positive (except for sucrose)	negative

Self-test 1.2a

Match the following terms with the items supplied:

1. aldose	a. polyhydroxyaldehyde or polyhydroxyketone
2. carbohydrate	b. containing many alcohol groups
3. disaccharide	c. simple sugar
4. ketose	d. double sugar
5. lactose	e. complex sugar
6. maltose	f. monosaccharide with aldehyde group
7. monosaccharide	g. monosaccharide with ketone group
8. polyhydroxy-	h. disaccharide yields negative test with $Cu(OH)_2$
9. polysaccharide	i. disaccharide yields positive tests with both $Cu(OH)_2$ and yeast
10. sucrose	j. disaccharide yields positive test with $Cu(OH)_2$ and does not ferment with yeast

Reading 1.1b - Read pages 228-232 in Medeiros, pages 272-286 in Sacheim & Schultz, and pages 323-324, 340-341, 362-363, 379-380, 388-391 & 394 in Holum.

Notes:

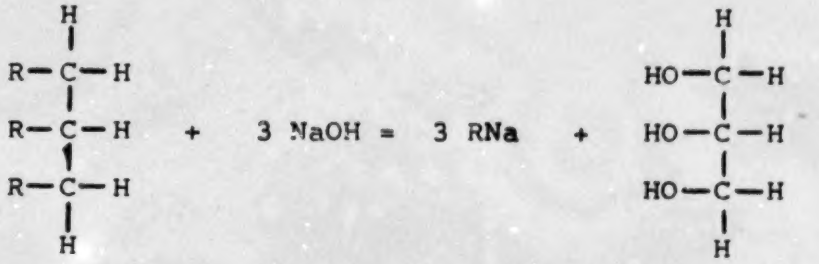
Simple lipids are esters of fatty acids. If the hydrolysis of a simple lipid yields a fatty acid and glycerol, the simple lipid is called a fat: some other alcohol and the simple lipid is called a wax.

$$\text{lipid} + \text{water} \xrightarrow{\text{hydrolysis}} \text{fatty acid} + \text{alcohol}$$

Fatty acids are straight-chain organic acids and may be saturated or unsaturated (contain one or more double bonds). Unsaturated fats and oils will readily combine with iodine. The iodine number of a fat or oil is the number of grams of iodine that will react with the double bonds present in 100 grams of the fat or oil. The higher the iodine number, the greater the degree of unsaturation of the fat or oil. In general, animal fats have a lower iodine number than do vegetable oils.

Both fats and oils are mixtures of various esters of the trihydric alcohol glycerol. One molecule of glycerol reacts with three molecules of a fatty acid to form an ester plus three water molecules. If the fatty acid is saturated, the product is a fat; if unsaturated, the product would be called an oil.

Saponification is the reaction of a fat with a strong base to produce glycerol and the salt of a fatty acid.



(fat) (soap) (glycerol)

The salt of the fatty acid is called a soap. With NaOH a bar soap is produced; with KOH the result is a liquid soap.

Calcium and magnesium ions present in "hard water" react with soap to form insoluble compounds seen as "the ring around the bathtub." Detergents are synthetic compounds--sodium salts of long chain alcohol sulfates--whose calcium and magnesium salts are soluble and leave no "ring" in the bathtub.

Since fats and oils are similar except for degree of saturation, the double bonds of oils may be converted to single bonds upon the addition of hydrogen. The process of changing vegetable oil to a fat by the addition of hydrogen in the presence of a catalyst is called hydrogenation. "Spry, crisco, and margarine" are prepared in this manner.

Compound lipids on hydrolysis yield a fatty acid, an alcohol, and some other type of compound. Phospholipids are those compounds containing fatty acids, alcohol, a nitrogen compound and phosphoric acid. Phospholipids are found in all tissues of the human body, expecially in the brain tissue.

Derived lipids are compounds derived from simple and compound lipids on hydrolysis. These include the sterols such as cholesterol and the sex hormones which are high molecular weight four-ring alcohols.

Self-test 1.2b

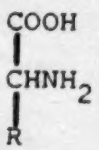
Match the following terms with the items supplied:

1. compound lipid	a. hydrolysis yields fatty acid plus alcohol
2. derived lipid	b. hydrolysis yields fatty acid plus glycerol
3. fat	c. salt of a fatty acid
4. hydrogenation	d. hydrolysis yiels fatty acid, alcohol plus some other compound
5. iodine number	e. hydrolysis yields fatty acid plus alcohol plus H_3PO_4 plus a nitrogen compound
6. oil	f. sterol
7. phospholipid	g. high iodine number
8. saponification	h. reaction of a fat and a base
9. simple lipid	i. reaction of oil and hydrogen
10. soap	j. degree of unsaturation

Reading 1.1c - Read pages 236-248 in Medeiros, pages 290-309 in Sackheim & Schultz, and pages 325-335, 345-355, 360-361, 364-378, & 395-400 in Holum.

Notes:

Proteins are composed of amino acids. Amino acids are organic acids having an amine ($-NH_2$) group attached to a chain containing an acid group (-COOH). The naturally occuring amino acids all have the amine group on the carbon atom next to the acid group (alpha carbon). The general formula thus is:



Amino acids are amphoteric--that is, they can react with either acids or bases. This is possible because amino acids contain a -COOH group, which is acidic, and an $-NH_2$ group, which is basic. Amino acids ionize in acid or basic solutions. The isoelectric point is the pH value at which there are an equal number of positive and negative ions.

Proteins consist of many amino acids joined together by what is called a peptide linkage. The amine part of one amino acid reacts with the acid part of another amino acid, water is eliminated, and the product is called a dipeptide. When four or more amino acids join together, the product is a polypeptide.

Amino acids are also optically active--that is, they can rotate a beam of polarized light. These are molecules whose mirror images are not superimposable. Your hands, for example, are also asymetric. The left is a "reflection" of the right, but the two are not identically superimposable. All the amino acids that exist in nature conform to one type--called the L-configuration. An interesting speculation is why the great preponderance of L-amino acids in nature and do D-amino acids exist in some other part of the universe?

Proteins are divided into three categories: simple, conjugate, and derived. Simple proteins, on hydrolysis, yield only amino acids or their derivatives. Conjugated proteins, on hydrolysis, yield amino acids plus some other type of compound. Derived proteins are protein derivatives and do not occur naturally.

Nucleoproteins are conjugated proteins--they contain a protein part and a nonprotein part, a nucleic acid. Two kinds of nucleic acids are deoxyriboneuclei acid (DNA) and ribonucleic acid (RNA). The hydrolysis of DNA results in phosphoric acid, deoxyribose (a pentose), two purines (adenine and guanine), and two pyrimidines (cytosine and thymine). The hydrolysis of RNA is similar except that the pentose is ribose and one of the pyrimidines is uracil (instead of thymine).

Nucleosides are purines or pyrimidines combined with a pentose. Nucleotides are the phosphate esters of the nucleosides. A nucleotide of particular interest is adenosine triphosphate (ATP) which is involved in the storage and release of energy in various cellular functions.

Self-test ◇1.2c◇

Match the following terms with the items supplied:

1. amino acid	a. contains $-NH_2$ and $-COOH$
2. ATP	b. pH where positive and negative ions are equal
3. conjugated protein	c. amine part of amino acid reacted with acid part of another amino acid
4. derived protein	d. rotates polarized light
5. DNA	e. hydrolysis yields amino acids
6. isoelectric point	f. hydrolysis yields amino acid plus another compound
7. optically active	g. protein derivatives
8. peptide linkage	h. nucleoprotein
9. polypeptide	i. nucleotide
10. simple protein	j. 4 or more amino acids

Reading 1.1d - Read pages 252-256 in Medeiros, pages 313-321 and 426-445 in Sackheim & Schultz, and pages 326, 335 & 344 in Holum.

Notes:

Enzymes are biological catalysts. Like other catalysts, enzymes alter the speed of a chemical reaction. Unlike other catalysts, enzymes are highly specific--that is, each enzyme will affect only one specific substance (called the substrate).

Many enzymes are conjugated proteins containing a protein part called the apoenzyme and a nonprotein part called the coenzyme. As proteins, enzymes undergo all the reactions that proteins do--may be coagulated by heat, alcohol, strong acids and alkaloid reagents. There is both an optimum temperature and optimum pH range at which the enzyme functions best. Coenzymes are not proteins and thus are not inactivated by heat. Vitamins are examples of coenzymes.

The desired system for naming enzymes utilizes the name of the substrate or the type of reaction involved, with the ending -ase. Thus the enzyme maltase acts on the sugar maltose and the hydrolases involve hydrolysis reactions.

Vitamins were originally thought to be vital amines or vitamines. However, they are not all amines so the "e" was dropped in the name. Vitamins are divided into two groups--those that are soluble in fat solvents (Vitamin A & D) and those soluble in water (such as Vitamin B_2 and C).

Self-test

Match the following terms with the items supplied:

1. apoenzyme	a. biological catalysts
2. carbohydrases	b. substance affected by enzyme
3. catalyst	c. enzyme functions best
4. coenzyme	d. protein part of enzyme
5. enzymes	e. non-protein part of enzyme
6. esterases	f. acts on urea
7. optimum temperature	g. hydrolysis of esters
8. substrate	h. water soluble or fat soluble
9. ureases	i. affects rate of reaction
10. vitamins	j. hydrolysis of carbohydrates

Conference

If you missed more than two questions in any part of Self-test 1.2, please consult your instructor. This is the only NO route available at this time.

Date:

Notes:

Introduction II

The environment should be the concern of everyone. Environmental pollution threaters the very existence of the civilization that produces it. Many pollutants are organic and all pollutants have an effect on organic matter--the living things of the environment. The solution lies in the involvement of all individuals.

The subject of environmental pollution is very broad. The following readings refer to only some of the many areas of potential interest. The intent is to provide opportunity for individual study and research.

Reading 2.1a - Read pages 259-266 in Medeiros, and pages 309 & 310 in Holum.

Notes:

The "drug scene" is very much a part of our present environment. What is a drug? How are drugs classified? What is the chemical structure of various types of drugs? What relationship exists between chemical structure and physiological effect? What are the psychological effects of using drugs? What is normal drug use and drug abuse? What is drug addiction and drug habituation? Who regulates the use of drugs? Is the "Delaney Clause" reasonable? Should the use of certain drugs be legalized? How does the answers to any of these questions relate to birth control pills?

Reading 2.1b - Read pages 270-286 and 154-173 in Medeiros and pages 186-202 in Holum.

Notes:

Air pollution is both visible (especially with a temperature inversion) and invisible. What are the various classes of air pollutants? What chemical reactions are responsible for the presence of these pollutants? How can we control these reactions? What would happen if we "Get the lead out" of all gasolines? Is zero air pollution feasible technologically or economically? How do catalytic control devices work on an automobile? What are the effects of air pollution?

Reading 2.1c - Read pages 290-301 and 130-150 in Medeiros and pages 96-97 & 153-156 in Holum.

Notes:

"Water, water everywhere,
Nor any drop to drink."

Although the plight of the Ancient Mariner may not yet be our fate, water is essential to all living things. What are the chemical and physical properties of water that make it essential? What are the sources and classes of polluted water? How does one measure the dissolved oxygen content of water? What is eutrophication? Why have phosphate detergents come under attack in recent years? What happens to an oil spill or the used oil from your car? What is the unexpected peril of swordfish? What is the "ouch, ouch" disease? What is the effect of thermal pollution of water? What are the chemical and physical processes that can be used to purify water? Which processes are economically feasible? Should "through the hull discharges" be permitted on boats?

Reading 2.1d - Read pages 306-310 in Medeiros.

Notes:

Are we in more danger from pesticides than from the pests? What are the "first-generation" pesticides? What are the "second-generation" pesticides? What are the "third-generation" like? What methods can be used to detect pesticide residues in the environment? What ethical issues are involved in the use of defoliants? Why was DDT, first synthesized in 1874, banned as of January, 1973 for virtually all uses in the United States? What agency, and by what authority, imposed this ban? Chemically, what is DDT? A different government agency, in September of 1972, banned the nonprescriptive sales of hexachlorophene--in use since 1941 in various health products. Why and who banned this effective germ killer?

Reading 2.1e - Read pages 310-311 in Medeiros and page 557 in Holum.

Notes:

What materials can be recycled? What materials are currently being collected (where and when) in your community for recycling? Why recyle at all? Is recycling economically feasible? What two famous chemical processes recycle or convert "waste" materials into useful byproducts?

Reading 2.1f - Read pages 312-313 in Medeiros.

Notes:

What happens to the trash and garbage from your home and/or the college? What other means of disposal are available? Which is the cheapest methods? How long can your present method accomodate the current and expected demands? Can any useful products be obtained from this refuse? What environmental considerations are involved with the various methods of solid waste disposal?

Reading 2.1g - Read pages 314-315 in Medeiros.

Notes:

Do you know exactly what you ate at your last meal? Did it contain any BHA, diglyceride, gum tragacanth, sodium benzoate, or EDTA? For what purposes are these permissible food additives used? Must all permissible ingredients be on the label of a food product? Can you identify all the ingredients listed on any food product label?

Are natural or organically grown foods better than synthetic foods? Why do newer "soft" margarines contain a higher percentage of polyunsaturates than the older formulations of margarine?

One food industry spokesman has been quoted as saying that "complete labeling of food with all ingredients and additives only serves to unduly alarm the consumer with long chemical names they don't understand." How do you feel about this statement? What is DES and why was it banned, in late 1972, in beef feed?

Reading 2.1h - Read pages 315-321 in Medeiros, pages 37-59 in Sackheim & Schultz, and pages 98 & 549-552 in Holum.

Notes:

Radioactive wastes have been called our chief pollutants because of their very long half-lives. Do you agree with this and why or why not? How would you evaluate the benefits of nuclear chemistry against the costs of human health and environmental degradation? What are the alternatives?

In view of the recent shortages of electrical power in the United States, comment on the price structure of electric power, i.e., the system of decreasing costs for increasing consumption. Does there exist an optional demand for power? Can we reduce power consumption without lowering our standard of living? What are the problems associated with nuclear reactors being used in place of hydroelectric generators?

Self-test 2.2

The usual type of evaluation has not been used here in order not to restrict the student.

As stated in the objective, you should submit a typewritten letter as indicated and be able to substantiate any statements therein.

Conference 2.3

This conference is actually part of Self-test 2.2

Date:

Notes:

EXAM

ILS Pac 8 Exam will consist of 20 questions

Objective 1 - Biochemical Molecules - 20 questions

Objective 2 - The Environment - typewritten letter and conference

See ILS Pac 0 (Student Directions) for Grading System Equivalents. Please remember that although the Exam is necessary for a grade, it may not be sufficient. You may also be asked to have a final conference with your instructor, particularly with regard to Objective 2.

CONFERENCE

Date:

Notes:

SUPPLEMENTARY MATERIAL

There are no computer modules available for this Pac.

Listen to any of the audio tapes available such as

Uses and Abuses of Biochemistry

Recollections of Sir Hans Kreb

The Development of Penicillin Drugs

The Story of Polythene

ANSWERS

Self-test 1.2a

1. f
2. a
3. d
4. g
5. j
6. i
7. c
8. b
9. e
10. h

Self-test 1.2b

1. d
2. f
3. b
4. i
5. j
6. g
7. e
8. h
9. a
10. c

Self-test 1.2c

1. a
2. i
3. f
4. g
5. h
6. b
7. d
8. c
9. j
10. e

Self-test 1.2d

1. d
2. j
3. i
4. e
5. a
6. g
7. c
8. b
9. f
10. h